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SEMICONDUCTOR PACKAGE CONNECTING METHOD, SEMICONDUCTOR PACKAGE CONNECTING WIRES AND SEMICONDUCTOR DEVICES

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(56) Prior Art Documents
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(57) Claim

1. A method for electrically connecting a semiconductor material to a substrate, said method comprising steps of:

(a) forming a connecting material, comprising a ball having a Brinell hardness number of $H_B 6$ or higher, by heating the tip of an alloy wire produced by drawing an alloy material produced by rapid-quenching an alloy, said alloy comprising:

a principal element selected from the group consisting of Pb and Sn;

0.01 - 10 wt% Sb; ~~and~~

0.01 - 10 wt% Zn, wherein said Sb and Zn form an intermetallic compound with a substrate upon connecting said semiconductor material to said substrate with said connecting material and said Zn occludes into said substrate;

(b) pulling the alloy wire away from a semiconductor material or a substrate after bonding the ball to an aluminium alloy wiring line formed on the semiconductor material or an aluminium alloy wiring line formed on the

substrate to separat the alloy wire from the ball and to leave the ball as a bump contact on the aluminium alloy wiring line of the semiconductor material or on that of the substrate; and

(c) electrically connecting the semiconductor material to the substrate through such bump contacts.

5. A connecting material for semiconductor material, comprising a ball having a Brinell hardness which is greater than 6, said ball being formed by heating the tip of an alloy wire, wherein said alloy wire is formed by drawing an alloy material produced by rapid-quenching an alloy, said alloy comprising:

a principal element selected from the group consisting of Pb and Sn;

0.01 - 10 wt% Sb; and

0.01 - 10 wt% Zn, wherein said Sb and Zn form an intermetallic compound with a substrate upon connecting said semiconductor material to said substrate with said connecting material and said Zn occludes into said substrate.

7. A connecting material according to claim 5, wherein the Brinell hardness number of the ball is in the range of H_B6 to H_B26.

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Form 10

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Complete Specification for the invention entitled:

"SEMICONDUCTOR PACKAGE CONNECTING METHOD, SEMICONDUCTOR PACKAGE CONNECTING WIRES AND SEMICONDUCTOR DEVICES"

The following statement is a full description of this invention, including the best method of performing it known to ~~me~~ us.

SPECIFICATION

SEMICONDUCTOR PACKAGE CONNECTING METHOD, SEMICONDUCTOR PACKAGE CONNECTING WIRES AND SEMICONDUCTOR DEVICES

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a semiconductor package connecting method and, more specifically, to a method of connecting a semiconductor package, such as a semiconductor chip, to a substrate by a wireless bonding process, particularly, a flip chip bonding process or a tape carrier bonding process, connecting wires for such a purpose, and semiconductor devices fabricated by a process employing such a connecting method.

Description of the Prior Art

A semiconductor package connecting method using bumps formed by a wire bonder and connecting materials for such a semiconductor package connecting method are disclosed in Japanese Patent Laid-open No. 63-301535. This known semiconductor package connecting method uses a fine alloy wire produced by quench solidifying an alloy containing Pb, Sn or In as a principal element. The tip of the alloy wire is heated to form a ball, the ball is attached to the wiring line of a semiconductor package or a substrate, and then the alloy wire is pulled off the ball to form a bump electrode on the wiring line. The semiconductor package and the substrate are connected by means of such bump electrodes.

Recently, aluminium alloys, such as Al-Si and Al-Cu-Si, have become used widely as wiring materials for semiconductor chips for their capability of suppressing electromigration and of improving the reliability of semiconductor chips. In attaching the ball directly to the aluminium alloy wiring line of a semiconductor package of a substrate by this known semiconductor package connecting method, the aluminium alloy wiring line must be heated in a flux containing $CuCl_2$, $ZnCl_2$, NH_4Cl, $SnCl_2$ or HCl to remove an oxide covering the surface of the aluminium alloy wiring line, which requires an additional process and time and increases the cost of the semiconductor device.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to form a bump electrode by using an alloy wire produced by quench solidification and to bond the bump electrode directly to an aluminium alloy wiring line.

In one aspect of the present invention, a method for electrically connecting a semiconductor material to a substrate comprises steps of (a) forming a connecting material, comprising a ball of a Brinell hardness number of 6 (hereinafter referred to as "H_B6") or higher, by heating the tip of an alloy wire produced by rapid-quenching an alloy, said alloy comprising:

a principal element selected from the group consisting of Pb and Sn;

0.01 - 10 wt% Sb; and

0.01 - 10 wt% Zn, wherein said Sb and Zn form an intermetallic compound with a substrate upon connecting said semiconductor material to said substrate with said connecting material and said Zn occludes into said substrate;

(b) pulling the alloy wire off the ball with the ball bonded to an aluminium alloy wiring line of a semiconductor material or a substrate to form a bump electrode on the aluminium alloy wiring line, and (c) connecting the semiconductor

material to the substrate with such bump electrodes.

In another aspect of the present invention, a connecting material for semiconductor material is a wire produced by rapid-quenching an alloy, said alloy comprising:

a principal element selected from the group consisting of Pb and Sn;

0.01 - 10 wt% Sb; and

0.01 - 10 wt% Zn, wherein said Sb and Zn form an intermetallic compound with a substrate upon connecting said semiconductor material to said substrate with said connecting material and said Zn occludes into said substrate; and said alloy being capable of forming a ball of H_B6 or higher when its tip is heated.

Preferably, the alloy forming the wire comprises one or more additive elements selected from the group consisting of Cu, Ni, Ag, Pt, Pd and P.

In a further aspect of the present invention, a semiconductor device comprises a semiconductor material electrically connected to a substrate by means of bump electrodes formed by bonding connecting material, comprising balls each of which is formed by heating the tip of an alloy wire formed from an alloy material produced by rapid-quenching an alloy, said alloy comprising:

a principal element selected from the group consisting of Pb and Sn;

0.01 - 10 wt% Sb; and

0.01 - 10 wt% Zn, wherein said Sb and Zn form an intermetallic compound with a substrate upon connecting said semiconductor material to said substrate with said connecting material and said Zn occludes into said substrate; wherein the wiring lines of the semiconductor material or the substrate are formed of an aluminium alloy, and balls serving as the bump electrodes have a hardness of H_B6 or higher.

Preferably, the alloy forming the wire comprises one or more additive elements selected from the group consisting of Cu, Ni, Ag, Pt, Pd and P.

The ball of the alloy of a hardness of H_B6 or higher disrupts the oxide film, which has a hardness in the order of

H_B12, and which covers the aluminium alloy wiring line. The disruption is sufficient to allow metallurgical bonding between the ball and aluminium alloy wiring line, by diffusion between the fresh ball and the fresh surface of the aluminium wiring line.

It is known that the pressurised contact of the ball, having a hardness of H_B6 or higher with the oxide layer of the aluminium wiring line having hardness of H_B12, causes disruption of the oxide layer by minute perforations or interstices being formed in the surface of the oxide layer. These perforations, which may be of molecular scale in size, are sufficient to allow metallurgical bonding.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the present invention will become more apparent from the following description taken in connection with the accompanying drawings, in which:

Figure 1 is a longitudinal sectional view of a semiconductor device in a preferred embodiment according to the present invention;

Figures 2 to 5 are enlarged fragmentary longitudinal views showing steps of connecting a semiconductor package to a substrate; and

Figure 6 is a longitudinal sectional view of a semiconductor device in another embodiment according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to Fig. 1, a semiconductor device A is of a so-called flip-chip mount type constructed by disposing a semiconductor chip (semiconductor package) 2 in the central area of the upper surface of a substrate 1, electrically connecting the aluminum alloy wiring lines 2a, i.e., wiring lines of an Al-Si alloy or an Al-Cu-Si alloy, of the semiconductor chip 2 to those of the wiring lines 1a, i.e., Cu lines plated with Sn or Au, arranged on the upper surface of the substrate 1 with bump contacts 3b, and sealing the semiconductor chip 2 and part of the wiring lines 1a of the substrate 1 with a protective resin 6, such as a silicone resin. The bump contacts 3b are formed previously by bonding balls 3a formed by heating the tip of an alloy wire 3, i.e., a connecting material, to the alloy wiring lines 2a of the semiconductor chip 2 through a procedure shown in Figs. 2 to 5.

The alloy wire 3 is formed of an alloy consisting of Pb, Sn or In as a principal element, and additive elements and produced by a quench solidifying process. The alloy wire 3 may contain one or some additive elements among Be, B, C, Mg, Al, Si, P, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Ge, Se, Zr, Nb, Mo, Pd, Ag, Cd, Sb, Te, Ir, Pt, Au, Tl and Bi. An alloy not containing Pb, Sn or In as the principal element may contain Pb, Sn or In as an additive element.

When quenched, many lattice defects are formed in the alloy forming the alloy wire 3, minute crystal grains develop in an unequilibriated phase to produce a forced solid solution of the component elements. When the alloy is drawn to produce the alloy wire 3, lattice defects are formed by work hardening, and the structure of the alloy is solution-hardened by the additive elements.

As shown in Fig. 2, the alloy wire 3 thus produced is passed through a capillary tube 4, and then the tip of the alloy wire 3 is heated with an electric torch 5 to form a ball 3a having a hardness of H_B 6 or higher. Then, as shown in Fig. 3, the capillary tube 4 is lowered to bond the ball 3a formed at the tip of the alloy wire 3 to the aluminium alloy wiring line 2a formed on the semiconductor chip 3.

The ball 3a having a hardness of H_B 6 or higher sufficiently disrupts the oxide film coating of the surface of the aluminium wiring line 2a, which has a hardness of the order of H_B 12, and the ball 3a is metallurgically bonded directly to the aluminium alloy wiring line 2a by diffusion between the surface of the ball 3a and the new surface of the aluminium alloy wiring line 2a. Subsequently, as shown in Fig. 4, the capillary 4 is raised to separate the ball 3a from the alloy wire 3 to leave the ball 3a as a bump contact 3b on the aluminium alloy wiring line 2a. When the tip of the alloy wire 3, namely, the ball 3a is heated, the unequilibriated phase disappears and the crystal grains grow large in the junction of the alloy wire 3 and the ball 3a to reduce the tensile strength of the junction, so that the

junction yields and breaks readily when the alloy wire 3 is raised by the capillary.

Then, as shown in Fig. 5, semiconductor chip 2 is placed on the substrate 1 with the bump contacts 3b bonded to the aluminium alloy wiring lines 2a in contact with the wiring lines 1a of the substrate 1, and then heat and pressure are applied to the bump contact 3b to connect electrically the aluminium alloy wiring lines 2a of the semiconductor chip 2 and the wiring lines 1a of the substrate and also to bond the semiconductor chip 2 to the substrate 1. Although the sphericity of the balls 3b can be improved by heating the balls 3b in the atmosphere of a flux of a chloride or an iodide before placing the balls 3b in contact with the wiring lines 1a of the substrate 1, the balls 3b may be bonded to the wiring lines 1a without causing them to reflow.

Fig. 6 shows a semiconductor device A in another embodiment according to the present invention. This semiconductor device A is of a so-called tape carrier bonding type, in which bump contacts 3b are formed on the aluminium alloy wiring lines 2a of a semiconductor chip 2, film leads 7 formed for example, by plating strips of a Cu foil with Sn or Au are bonded to the bump contacts 3b and the wiring lines 1a of a substrate 1.

In the foregoing embodiments, the aluminium alloy wiring lines 2a are formed on the semiconductor chip 2 and the balls 3a are bonded to the aluminium alloy wiring lines 2a as the bump contacts 3b. The wiring lines 1a of the substrate 1 may be formed of an aluminium alloy and the balls 3a may be bonded to the wiring lines 1a of the substrate 1 as the bump contacts 3b.

Tables 1 to 27 show the properties of alloys in comparison with those of controls in terms of the respective compositions of alloys forming alloy wires, the ball forming property of the alloy wires, the hardness of balls formed by heating the alloy wires, and the capability of bonding to the Al-Si alloy wiring lines. Examples 26-33 of each of Tables 6, 8, 10 and 12; Examples 13-33 of Table 24; Examples 1-15 of

Table 25; Examples 9-33 of Table 26; and Example 1 of Table 27 illustrate alloys in accordance with the present invention.

The ball forming property is evaluated by the shape of a ball formed by arc discharge between the tip of a sample alloy wire passed through a ceramic capillary tube and an electrode disposed near the tip of the sample alloy wire in an argon gas atmosphere containing 5% in volume hydrogen gas. In the tables, a circular mark indicates that the ball has satisfactory sphericity and smooth surface morphology.

Thus, the present invention has the following advantages.

The ball of a hardness of H_B 6 or higher formed on the tip of the alloy wire produced by drawing a quench solidified alloy disrupts an oxide film coating the surface of the aluminium alloy wiring line, and the ball and the aluminium alloy wiring line are bonded together metallurgically by mutual diffusion between the new surface of the aluminium alloy wiring line and the new surface of the ball, and hence the ball formed on the tip of the alloy wire can be directly joined as a bump contact to the aluminium alloy wiring line.

Thus, the present invention enables the omission of a step of removing the oxide film coating the surface of the aluminium alloy wiring line, which reduces time and cost for assembling the semiconductor device.

Although the invention has been described in its preferred forms with a certain degree of particularity, obviously, many changes and variations are possible therein. It is therefore to be understood that the present invention may be practised otherwise than as specifically described herein without departing from the scope and spirit thereof.

Table 1

Composition (% by wt.)													Ball Formation	H_B	Bonding Property
Pb	Sn	In	Sb	Cu	Ni	Bi	Zn	Ag	Au	Pt	Pd	Others			
Balance	2		0.5	0.05									○	5	Bad
Balance	2		0.5	0.1									○	5	Bad
Balance	2		0.5	1.0									○	5	Bad
Balance	2		0.5	0.05					0.1				○	5	Bad
Balance	2		0.5	0.1					0.3				○	5	Bad
Balance	2		0.5	0.1					0.5				○	5	Bad
Balance	2		0.5	0.5					1.0				○	6	Good
Balance	2		0.5	1.0					1.5				○	6	Good
Balance	2		0.5	0.05						0.1			○	5	Bad
Balance	2		0.5	0.1						0.3			○	5	Bad
Balance	2		0.5	0.1						0.5			○	5	Bad
Balance	2		0.5	0.5						1.0			○	6	Good
Balance	2		0.5	1.0						1.5			○	6	Good
Balance	2		0.5	0.05							0.1		○	5	Bad
Balance	2		0.5	0.1							0.3		○	5	Bad
Balance	2		0.5	0.1							0.5		○	5	Bad
Balance	2		0.5	0.5							1.0		○	6	Good
Balance	2		0.5	1.0							1.5		○	6	Good
Balance	2		0.5		0.05				0.1				○	5	Bad
Balance	2		0.5		0.1				0.3				○	5	Bad
Balance	2		0.5		0.1				0.5				○	5	Bad
Balance	2		0.5		0.5				1.0				○	6	Good
Balance	2		0.5		1.0				1.5				○	6	Good
Balance	2		0.5		0.05					0.1			○	5	Bad
Balance	2		0.5		0.1					0.3			○	5	Bad
Balance	2		0.5		0.1					0.5			○	5	Bad
Balance	2		0.5		0.5					1.0			○	6	Good
Balance	2		0.5		1.0					1.5			○	6	Good
Balance	2		0.5		0.05						0.1		○	5	Bad
Balance	2		0.5		0.1						0.3		○	5	Bad
Balance	2		0.5		0.1						0.5		○	5	Bad
Balance	2		0.5		0.5						1.0		○	6	Good
Balance	2		0.5		1.0						1.5		○	6	Good

Table 19

	Composition (% by wt.)												Ball Formation	H_v	Bonding Property
Pb	Sn	In	Sb	Cu	Ni	Bi	Zn	Ag	Au	Pt	Pd	P			
10	Balance			0.1	0.1			4.0					○	10	Good
40	Balance			0.01	0.99			0.1					○	12	Good
40	Balance			0.1	0.8			0.5					○	12	Good
40	Balance			0.3	0.6			3.0					○	13	Good
40	Balance			0.4	0.5			1.0					○	13	Good
40	Balance			0.5	0.3			4.0					○	12	Good
40	Balance			0.5	0.6			4.0					○	13	Good
40	Balance			0.6	0.1			3.0					○	12	Good
40	Balance			0.6	0.4			4.0					○	12	Good
40	Balance			0.6	0.5			4.0					○	13	Good
40	Balance			0.6	0.7			7.0					○	13	Good
40	Balance			0.7	0.1			8.0					○	12	Good
40	Balance			0.99	0.01			10.0					○	12	Good
	Balance				1.0								○	12	Good
	Balance			0.1	0.9			4.0					○	14	Good
	Balance			0.4	0.6			10.0					○	14	Good
	Balance			0.5	0.5								○	13	Good
	Balance			0.7	0.3								○	13	Good
	Balance			1.0									○	12	Good
	Balance			2.0									○	12	Good
	Balance				2.0								○	12	Good
	Balance							0.01					○	10	Good
	Balance							0.1					○	10	Good
	Balance							1.0					○	12	Good
	Balance							5.0					○	12	Good
	Balance							10.0					○	13	Good
	Balance							20.0					○	15	Good
	Balance								0.01				○	11	Good
	Balance								0.1				○	10	Good
	Balance								1.0				○	12	Good
	Balance								5.0				○	12	Good
	Balance								10.0				○	13	Good
	Balance								20.0				○	15	Good

Table 20

	15	Good

Table 20

Composition (% by wt.)													Ball Formation	H_v	Bonding Property
Pb	Sn	In	Sb	Cu	Ni	Bi	Zn	Ag	Au	Pt	Pd	P			
	Balance									0.01			○	10	Good
	Balance									0.1			○	10	Good
	Balance									1.0			○	12	Good
	Balance									5.0			○	12	Good
	Balance									10.0			○	13	Good
	Balance									20.0			○	15	Good
	Balance										0.01		○	10	Good
	Balance										0.1		○	10	Good
	Balance										1.0		○	12	Good
	Balance										5.0		○	12	Good
	Balance										10.0		○	13	Good
	Balance										20.0		○	15	Good
	Balance		0.01					0.01					○	11	Good
	Balance		0.1					0.1					○	11	Good
	Balance		0.1					1.0					○	12	Good
	Balance		1.0					3.0					○	13	Good
	Balance		2.0					5.0					○	14	Good
	Balance		3.0					5.0					○	15	Good
	Balance		4.0					5.0					○	16	Good
	Balance		5.0					7.0					○	16	Good
	Balance		5.0					10.0					○	17	Good
	Balance		10.0					20.0					○	20	Good
	Balance		0.01						0.01				○	11	Good
	Balance		0.1						0.1				○	11	Good
	Balance		1.0						1.0				○	12	Good
	Balance		3.0						3.0				○	14	Good
	Balance		5.0						10.0				○	17	Good
	Balance		10.0						20.0				○	20	Good
	Balance		0.01							0.01			○	11	Good
	Balance		0.1							0.1			○	11	Good
	Balance		1.0							1.0			○	12	Good
	Balance		3.0							5.0			○	14	Good
	Balance		5.0							10.0			○	17	Good

Table 21

Pb	Sn	In	Sb	Cu	Ni	Bi	Zn	Ag	Au	Pt	Pd	P	Ball Formation	Hn	Bonding Property
	Balance		10.0							20.0			○	20	Good
	Balance		0.01								[illegible]		○	11	Good
	Balance		0.1								0.1		○	11	Good
	Balance		1.0								1.0		○	12	Good
	Balance		3.0								5.0		○	13	Good
	Balance		5.0								10.0		○	17	Good
	Balance		10.0								20.0		○	20	Good
	Balance						0.01	0.01					○	10	Good
	Balance						0.1	0.1					○	10	Good
	Balance						0.5	1.0					○	12	Good
	Balance						0.5	5.0					○	12	Good
	Balance						1.0	5.0					○	13	Good
	Balance						3.0	5.0					○	13	Good
	Balance						7.0	10.0					○	16	Good
	Balance						10.0	20.0					○	20	Good
	Balance						0.01	0.01				0.0001	○	10	Good
	Balance						0.1	1.0				0.005	○	11	Good
	Balance						0.2	5.0				0.025	○	12	Good
	Balance						3.0	10.0				0.1	○	14	Good
	Balance						0.01		0.01				○	10	Good
	Balance						1.0		1.0				○	12	Good
	Balance						3.0		5.0				○	13	Good
	Balance						10.0		20.0				○	20	Good
	Balance						0.01		0.01			0.0001	○	10	Good
	Balance						0.1		1.0			0.005	○	11	Good
	Balance						0.2		5.0			0.025	○	12	Good
	Balance						3.0		10.0			0.1	○	14	Good
	Balance						0.01			0.01			○	10	Good
	Balance						1.0			1.0			○	12	Good
	Balance						3.0			5.0			○	13	Good
	Balance						10.0			20.0			○	20	Good
	Balance						0.01			0.01		0.0001	○	10	Good
	Balance						0.1			1.0		0.005	○	11	Good

Table 22

													○	11	Good

Table 22

Composition (% by wt.)													Ball Formation	H_v	Bonding Property
Pb	Sn	In	Sb	Cu	Ni	Bi	Zn	Ag	Au	Pt	Pd	P			
	Balance						0.2			5.0		0.025	○	12	Good
	Balance						3.0			10.0		0.1	○	14	Good
	Balance						0.01				0.01		○	10	Good
	Balance						1.0				1.0		○	12	Good
	Balance						3.0				5.0		○	13	Good
	Balance						10.0				20.0		○	20	Good
	Balance						0.01				0.01	0.0001	○	10	Good
	Balance						0.1				1.0	0.005	○	11	Good
	Balance						0.2				5.0	0.025	○	12	Good
	Balance						3.0				10.0	0.1	○	14	Good
	Balance		0.01	0.01				0.01					○	11	Good
	Balance		0.1	0.1				0.1					○	11	Good
	Balance		0.1	0.1				1.0					○	12	Good
	Balance		1.0	0.5				3.0					○	13	Good
	Balance		2.0	0.7				5.0					○	14	Good
	Balance		3.0	1.0				5.0					○	15	Good
	Balance		4.0	1.0				5.0					○	16	Good
	Balance		5.0	1.0				7.0					○	17	Good
	Balance		5.0	1.0				10.0					○	18	Good
	Balance		10.0	2.0				20.0					○	24	Good
	Balance		0.01	0.01					0.01				○	11	Good
	Balance		0.1	0.1					0.1				○	11	Good
	Balance		1.0	0.5					1.0				○	12	Good
	Balance		3.0	1.0					5.0				○	14	Good
	Balance		5.0	1.5					10.0				○	18	Good
	Balance		10.0	2.0					20.0				○	24	Good
	Balance		0.01	0.01						0.01			○	11	Good
	Balance		0.1	0.1						0.1			○	11	Good
	Balance		1.0	0.5						1.0			○	12	Good
	Balance		3.0	1.0						5.0			○	14	Good
	Balance		5.0	1.5						10.0			○	18	Good
	Balance		10.0	2.0						20.0			○	24	Good
	Balance		0.01	0.01							0.01		○	11	Good

Table 23

Composition (% by wt.)													Ball Formation	H_0	Bonding Property
Pb	Sn	In	Sb	Cu	Ni	Bi	Zn	Ag	Au	Pt	Pd	P			
	Balance		0.1	0.1							0.1		○	11	Good
	Balance		1.0	0.5							1.0		○	12	Good
	Balance		3.0	1.0							5.0		○	14	Good
	Balance		5.0	1.5							10.0		○	18	Good
	Balance		10.0	2.0							20.0		○	24	Good
	Balance		0.01		0.01			0.01					○	11	Good
	Balance		0.1		0.1			0.1					○	11	Good
	Balance		0.1		0.1			1.0					○	12	Good
	Balance		1.0		0.5			3.0					○	13	Good
	Balance		2.0		0.7			5.0					○	14	Good
	Balance		3.0		1.0			5.0					○	15	Good
	Balance		4.0		1.0			5.0					○	16	Good
	Balance		5.0		1.0			7.0					○	17	Good
	Balance		5.0		1.0			10.0					○	18	Good
	Balance		10.0		2.0			20.0					○	24	Good
	Balance		0.01		0.01				0.01				○	11	Good
	Balance		0.1		0.1				0.1				○	11	Good
	Balance		0.1		0.1				1.0				○	12	Good
	Balance		1.0		0.5				3.0				○	13	Good
	Balance		2.0		0.7				5.0				○	14	Good
	Balance		3.0		1.0				5.0				○	15	Good
	Balance		4.0		1.0				5.0				○	16	Good
	Balance		5.0		1.0				7.0				○	17	Good
	Balance		5.0		1.0				10.0				○	18	Good
	Balance		10.0		2.0				20.0				○	24	Good
	Balance		0.01		0.01					0.01			○	11	Good
	Balance		0.1		0.1					0.1			○	11	Good
	Balance		0.1		0.1					1.0			○	12	Good
	Balance		1.0		0.5					3.0			○	13	Good
	Balance		2.0		0.7					5.0			○	14	Good
	Balance		3.0		1.0					5.0			○	15	Good
	Balance		4.0		1.0					5.0			○	16	Good
	Balance		5.0		1.0					7.0			○	17	Good

Table 24

Table 24

Composition (% by wt.)													Ball Formation	H_v	Bonding Property
Pb	Sn	In	Sb	Cu	Ni	Bi	Zn	Ag	Au	Pt	Pd	P			
	Balance		5.0		1.0					10.0			○	18	Good
	Balance		10.0		2.0					20.0			○	24	Good
	Balance		0.01		0.01						0.01		○	11	Good
	Balance		0.1		0.1						0.1		○	11	Good
	Balance		0.1		0.1						1.0		○	12	Good
	Balance		1.0		0.5						3.0		○	13	Good
	Balance		2.0		0.7						5.0		○	14	Good
	Balance		3.0		1.0						5.0		○	15	Good
	Balance		1.0		1.0						5.0		○	16	Good
	Balance		5.0		1.0						7.0		○	17	Good
	Balance		5.0		1.0						10.0		○	18	Good
	Balance		10.0		2.0						20.0		○	22	Good
	Balance		0.01				0.01	0.01					○	11	Good
	Balance		0.1				0.1	0.1					○	11	Good
	Balance		0.5				0.5	1.0					○	12	Good
	Balance		0.5				0.5	5.0					○	13	Good
	Balance		1.0				1.0	5.0					○	14	Good
	Balance		1.0				3.0	5.0					○	15	Good
	Balance		5.0				7.0	10.0					○	19	Good
	Balance		10.0				10.0	20.0					○	26	Good
	Balance		0.01				0.01	0.01				0.0001	○	11	Good
	Balance		0.5				0.1	1.0				0.005	○	12	Good
	Balance		1.0				0.2	5.0				0.025	○	13	Good
	Balance		5.0				3.0	10.0				0.1	○	18	Good
	Balance		0.01				0.01		0.01				○	11	Good
	Balance		0.5				1.0		1.0				○	12	Good
	Balance		5.0				3.0		5.0				○	17	Good
	Balance		10.0				10.0		20.0				○	26	Good
	Balance		0.01				0.01		0.01			0.0001	○	11	Good
	Balance		0.5				0.1		1.0			0.005	○	12	Good
	Balance		1.0				0.2		5.0			0.025	○	13	Good
	Balance		5.0				8.0		10.0			0.1	○	18	Good
	Balance		0.01				0.01			0.01			○	11	Good

Table 25

es	Composition (% by wt.)													Ball Formation	H	Bonding Property
	Pb	Sn	In	Sb	Cu	Ni	Bi	Zn	Ag	Au	Pt	Pd	P			
1		Balance		0.5				1.0			1.0			○	12	Good
2		Balance		5.0				3.0			5.0			○	17	Good
3		Balance		10.0				10.0			20.0			○	26	Good
4		Balance		0.01				0.01			0.01		0.0001	○	11	Good
5		Balance		0.5				0.1			1.0		0.005	○	12	Good
6		Balance		1.0				0.2			5.0		0.025	○	13	Good
7		Balance		5.0				3.0			10.0		0.1	○	18	Good
8		Balance		0.01				0.01				0.01		○	11	Good
9		Balance		0.5				1.0				1.0		○	12	Good
10		Balance		5.0				3.0				5.0		○	17	Good
11		Balance		10.0				10.0				20.0		○	26	Good
12		Balance		0.01				0.01				0.01	0.0001	○	11	Good
13		Balance		0.5				0.1				1.0	0.005	○	12	Good
14		Balance		1.0				0.2				5.0	0.025	○	13	Good
15		Balance		5.0				3.0				10.0	0.1	○	18	Good
16		Balance			0.01			0.01	0.01					○	11	Good
17		Balance			0.5			1.0	1.0					○	12	Good
18		Balance			1.0			1.0	5.0					○	14	Good
19		Balance			2.0			10.0	20.0					○	24	Good
20		Balance			0.01			0.01		0.01				○	11	Good
21		Balance			0.5			1.0		1.0				○	12	Good
22		Balance			2.0			10.0		20.0				○	24	Good
23		Balance			0.01			0.01			0.01			○	11	Good
24		Balance			0.5			1.0			1.0			○	12	Good
25		Balance			2.0			10.0			20.0			○	24	Good
26		Balance			0.01			0.01				0.01		○	11	Good
27		Balance			0.5			1.0				1.0		○	12	Good
28		Balance			2.0			10.0				20.0		○	24	Good
29		Balance				0.01		0.01	0.01					○	11	Good
30		Balance				0.5		1.0	1.0					○	12	Good
31		Balance				1.0		1.0	5.0					○	14	Good
32		Balance				2.0		10.0	20.0					○	24	Good
33		Balance				0.01		0.01		0.01				○	11	Good

26

Composition (% by wt.)													Ball Formation	H_s	Bonding Property
Pb	Sn	In	Sb	Cu	Ni	Bi	Zn	Ag	Au	Pt	Pd	P			
	Balance				0.5		1.0		1.0				○	12	Good
	Balance				2.0		10.0		20.0				○	24	Good
	Balance				0.01		0.01			0.01			○	11	Good
	Balance				0.5		1.0			1.0			○	12	Good
	Balance				2.0		10.0			20.0			○	24	Good
	Balance				0.01		0.01				0.01		○	11	Good
	Balance				0.5		1.0				1.0		○	12	Good
	Balance				2.0		10.0				20.0		○	24	Good
	Balance		0.01	0.01			0.01	0.01					○	11	Good
	Balance		1.0	0.5			1.0	1.0					○	13	Good
	Balance		5.0	1.0			1.0	5.0					○	15	Good
	Balance		10.0	2.0			10.0	20.0					○	26	Good
	Balance		0.01	0.01			0.01		0.01				○	11	Good
	Balance		1.0	0.5			1.0		1.0				○	13	Good
	Balance		10.0	2.0			10.0		10.0				○	26	Good
	Balance		0.01	0.01			0.01			0.01			○	11	Good
	Balance		1.0	0.5			1.0			1.0			○	13	Good
	Balance		10.0	2.0			10.0			10.0			○	26	Good
	Balance		0.01	0.01			0.01				0.01		○	11	Good
	Balance		1.0	0.5			1.0				1.0		○	13	Good
	Balance		10.0	2.0			10.0				10.0		○	26	Good
	Balance		0.01		0.01		0.01	0.01					○	11	Good
	Balance		1.0		0.5		1.0	1.0					○	13	Good
	Balance		5.0		1.0		1.0	5.0					○	15	Good
	Balance		10.0		2.0		10.0	20.0					○	26	Good
	Balance		0.01		0.01		0.01		0.01				○	11	Good
	Balance		1.0		0.5		1.0		1.0				○	13	Good
	Balance		10.0		2.0		10.0		10.0				○	26	Good
	Balance		0.01		0.01		0.01			0.01			○	11	Good
	Balance		1.0		0.5		1.0			1.0			○	13	Good
	Balance		10.0		2.0		10.0			10.0			○	26	Good
	Balance		0.01		0.01		0.01				0.01		○	11	Good
	Balance		1.0	0.5			1.0				1.0		○	13	Good

Table 27

Composition (% by wt.)													Ball Formation	Hv	Bonding Property
Pb	Sn	In	Sb	Cu	Ni	Bi	Zn	Ag	Au	Pt	Pd	P			
	Balance		10.0	2.0			10.0				10.0		○	26	Good

The claims defining the invention are as follows:

1. A method for electrically connecting a semiconductor material to a substrate, said method comprising steps of:

(a) forming a connecting material, comprising a ball having a Brinell hardness number of H_B6 or higher, by heating the tip of an alloy wire produced by drawing an alloy material produced by rapid-quenching an alloy, said alloy comprising:

a principal element selected from the group consisting of Pb and Sn;

0.01 - 10 wt% Sb; and

0.01 - 10 wt% Zn, wherein said Sb and Zn form an intermetallic compound with a substrate upon connecting said semiconductor material to said substrate with said connecting material and said Zn occludes into said substrate;

(b) pulling the alloy wire away from a semiconductor material or a substrate after bonding the ball to an aluminium alloy wiring line formed on the semiconductor material or an aluminium alloy wiring line formed on the substrate to separate the alloy wire from the ball and to leave the ball as a bump contact on the aluminium alloy wiring line of the semiconductor material or on that of the substrate; and

(c) electrically connecting the semiconductor material to the substrate through such bump contacts.

2. A method according to claim 1, wherein the alloy wire is passed through a capillary tube employed in a wire bonder, and the balls are bonded to the aluminium alloy wiring lines by a wire bonding method.

3. A method according to claim 1, wherein the alloy forming the alloy wire comprises at least one element selected from the group consisting of Cu, Ni, Ag, Pt, Pd and P.

4. A method according to claim 1, wherein the Brinell hardness number of the ball is in the range of H_B6 to H_B26.

5. A connecting material for semiconductor material comprising a ball having a Brinell hardness which is greater than 6, said ball being formed by heating the tip of an alloy wire, wherein said alloy wire is formed by drawing an alloy material produced by rapid-quenching an alloy, said alloy comprising:

a principal element selected from the group consisting of Pb and Sn;

0.01 - 10 wt% Sb; and

0.01 - 10 wt% Zn, wherein said Sb and Zn form an intermetallic compound with a substrate upon connecting said semiconductor material to said substrate with said connecting material and said Zn occludes into said substrate.

6. A connecting material according to claim 5, wherein the alloy of the alloy wire comprises at least one element selected from the group consisting of Cu, Ni, Ag, Pt, Pd and P.

7. A connecting material according to claim 5, wherein the Brinell hardness number of the ball is in the range of H_B6 to H_B26.

8. A semiconductor device comprising:

a substrate; and

a semiconductor material electrically connected to the substrate through bump contacts formed by bonding connecting material, comprising balls each of which is formed by heating the tip of an alloy wire formed from an alloy material produced by rapid-quenching an alloy, said alloy comprising:

a principal element selected from the group consisting of Pb and Sn;

0.01 - 10 wt% Sb; and

0.01 - 10 wt% Zn, wherein said Sb and Zn form an intermetallic compound with a substrate upon connecting said semiconductor material to said substrate with said connecting material and said Zn occludes into said substrate;

wherein wiring lines formed on the substrate or on the semiconductor material are formed of an aluminium alloy, and the Brinell hardness number of the balls is H_B6 or higher.

9. A semiconductor device according to Claim 8, wherein the alloy wire is passed through a capillary tube employed in a wire bonder, and the balls are bonded to the aluminium alloy wiring lines by a wire bonding method.

10. A semiconductor device according to Claim 8, wherein the alloy forming the alloy wire comprises at least one element selected from the group consisting of Cu, Ni, Ag, Pt, Pd and P.

11. A semiconductor device according to Claim 8, wherein the Brinell hardness number of the balls is in the range of H_B6 to H_B26.

12. A semiconductor device according to Claim 8, wherein the semiconductor device is of a flip-chip mount type.

13. A semiconductor device according to Claim 8, wherein the semiconductor device is of tape carrier bonding type.

14. A method according to any one of Claims 1 to 4, substantially as hereinbefore described, and with reference to and as illustrated in the accompanying drawings.

15. A connecting material according to any one of Claims 5 to 7, substantially as hereinbefore described, and with reference to and as illustrated in the accompanying drawings.

16. A semiconductor device according to any one of Claims 8 to 13, substantially as hereinbefore described, and with reference to and as illustrated in the accompanying drawings.

DATED this 16th day of September, 1993.

TANAKA DENSHI KOGYO KABUSHIKI KAISHA
By its Patent Attorneys
R K MADDERN & ASSOCIATES

ABSTRACT OF THE DISCLOSURE

The invention comprises the following;

(i) a method of electrically connecting a semiconductor package to a substrate by using bump contacts formed by heating the tip of an alloy wire and directly bonding the ball formed to aluminium alloy wiring lines,

(ii) an alloy wire for such a purpose, and

(iii) a semiconductor device constructed by electrically connecting a semiconductor package to a substrate by such a method. The alloy wire is produced by drawing an alloy material produced by quench solidifying an alloy containing Pb, Sn or In as a principal element, and an additive element or additive elements. The tip of the alloy wire is heated to form a ball to be bonded to the aluminium alloy wiring line as a bump contact. The Brinell hardness number of the ball is H_B 6 or higher.

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FIG. 1

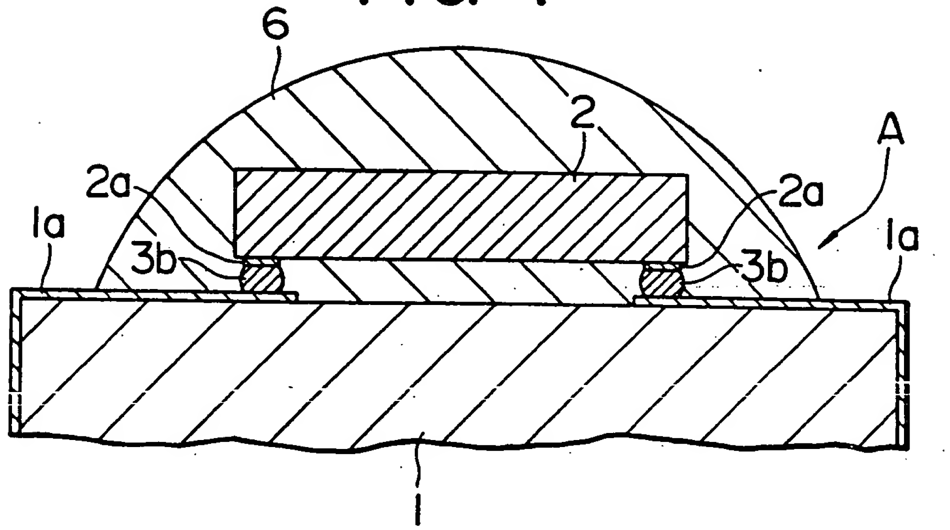

FIG. 2

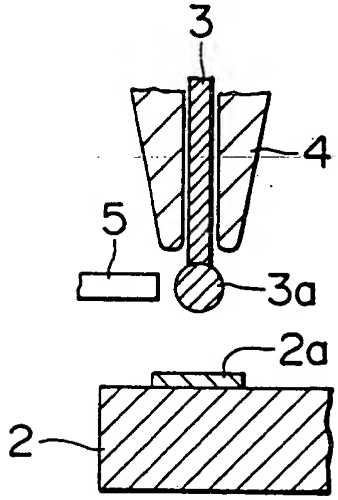

FIG. 3

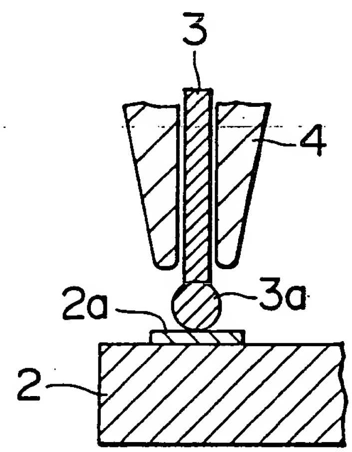

FIG. 4

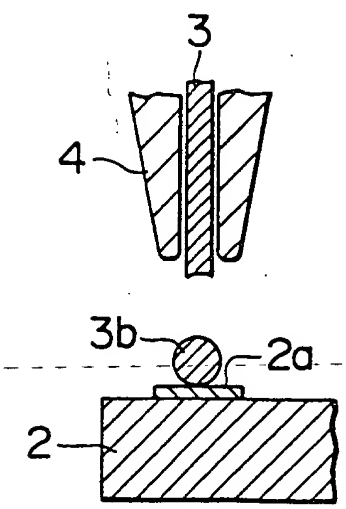

FIG. 5

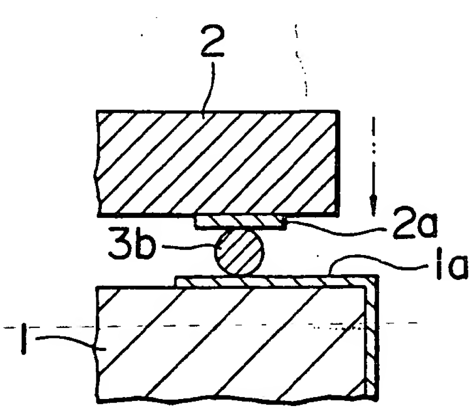

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FIG. 6